



What We Have Learned from HIRDLS

Looking Beyond the Blockage

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HIRDLS as Planned



High Resolution Dynamics Limb Sounder (HIRDLS) - a 21 channel limb-scanning IR radiometer

Jointly developed by US and UK

Goals:

Measurements of T, O₃, H₂O, NO₂, HNO₃, N₂O₅, N₂O, ClONO₂, CFC11, CFC12, CH₄ and aerosols,

Globally, 90° S to 90° N,

Higher Resolution than previous-
1 km vertical x 500 km lat. x 500 km
long.



**Viewing
Aperture**



HIRDLS in Orbit



Measurements Achieved:

Measurements of T, O₃, H₂O, NO₂, HNO₃, N₂O₅, N₂O, ClONO₂, CFC11, CFC12, and aerosols.

Coverage:, 63° S to 82° N,

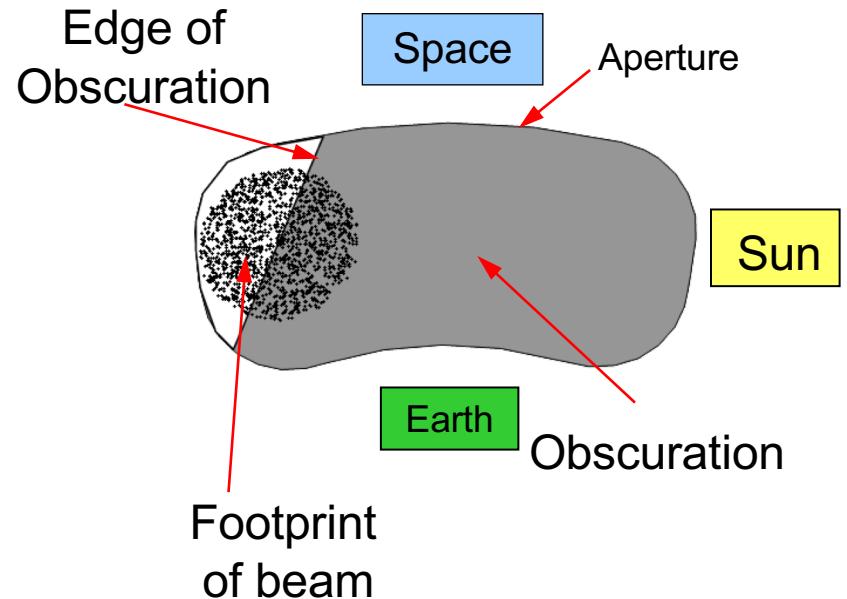
Higher Resolution than previous-

1 km vertical x 100 km lat 13° lon

Jan 2005 – March 2008

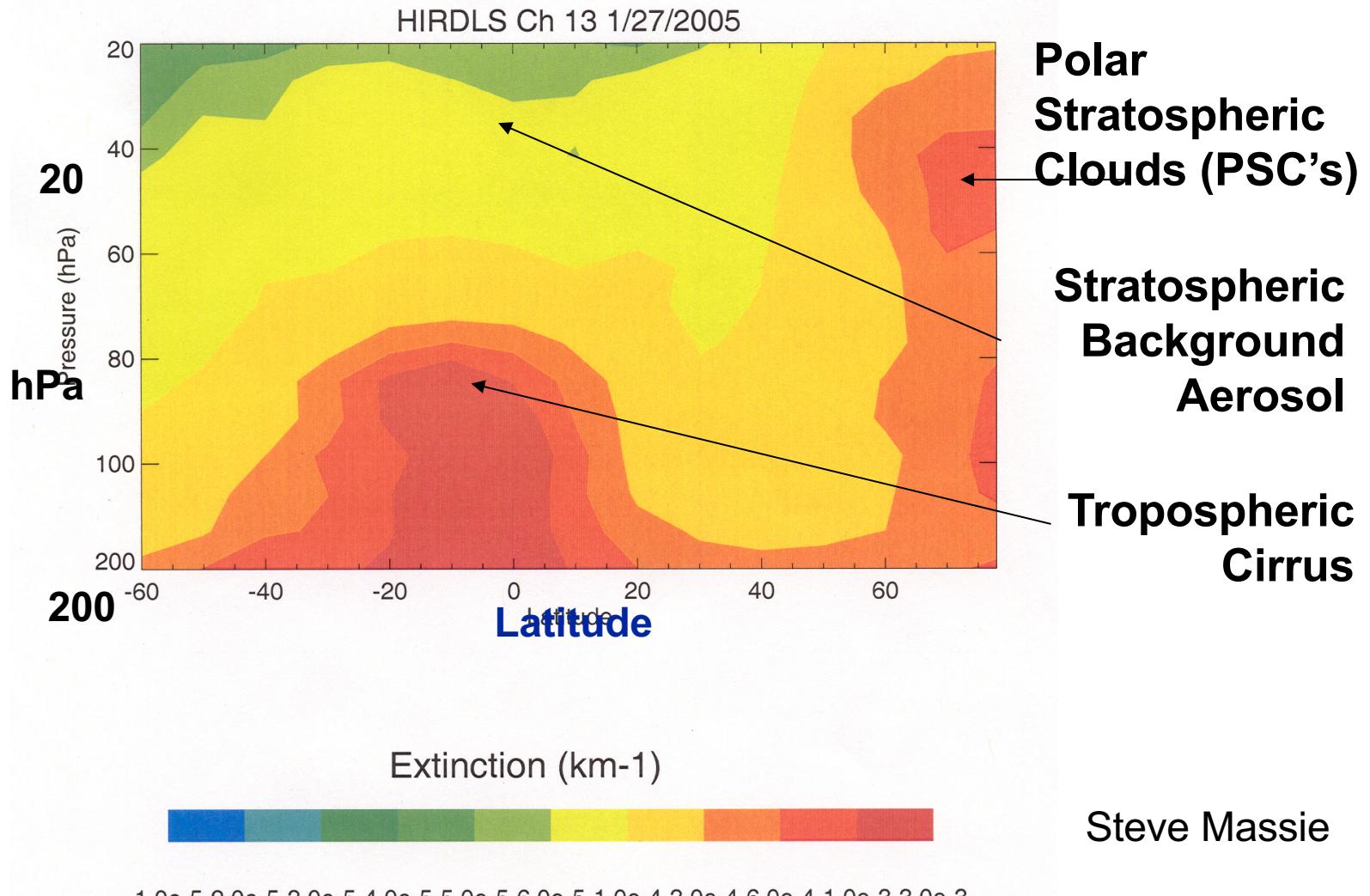
Unique features of HIRDLS data:

- 1 km vertical resolution
- Ability to see stratospheric particulates





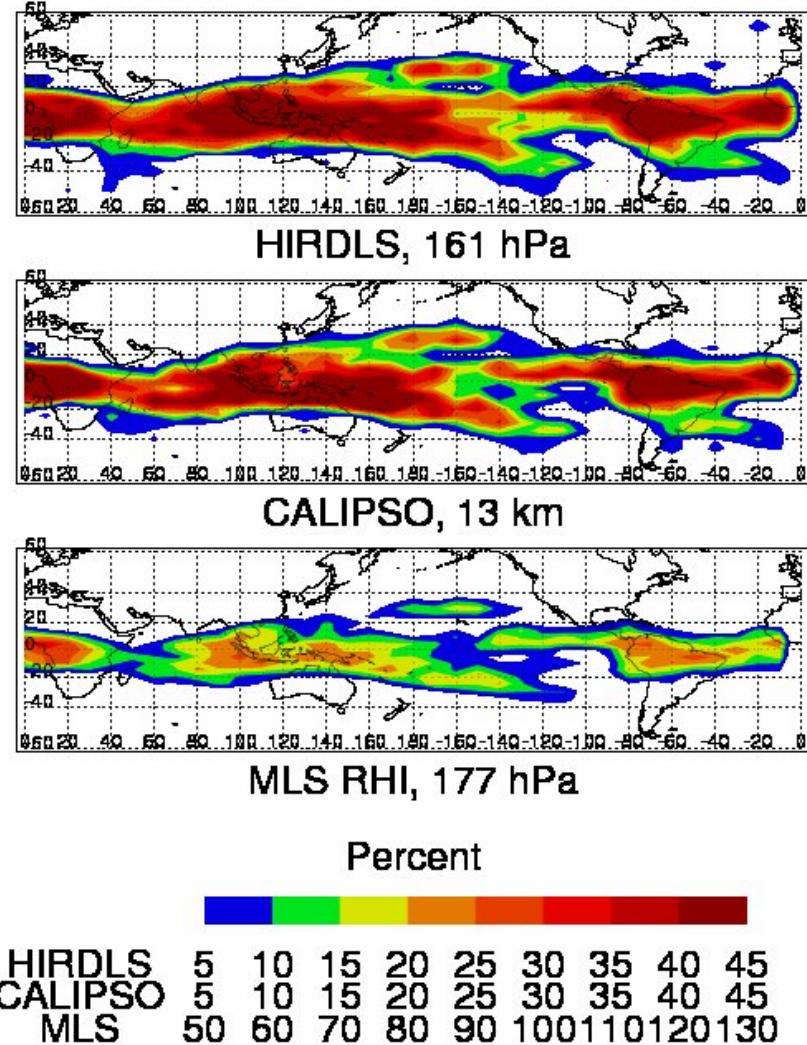
One Day's Retrieval for Clouds and Aerosols- 1/27/05





Ability to Detect High Cirrus

April 2007



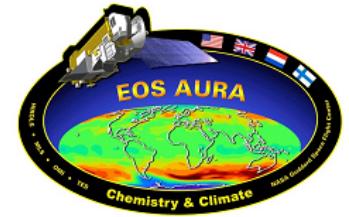
The Ability to see
Monthly Variations
Is a
New Capability

Comparison to
CALIPSO shows
mutual validation.

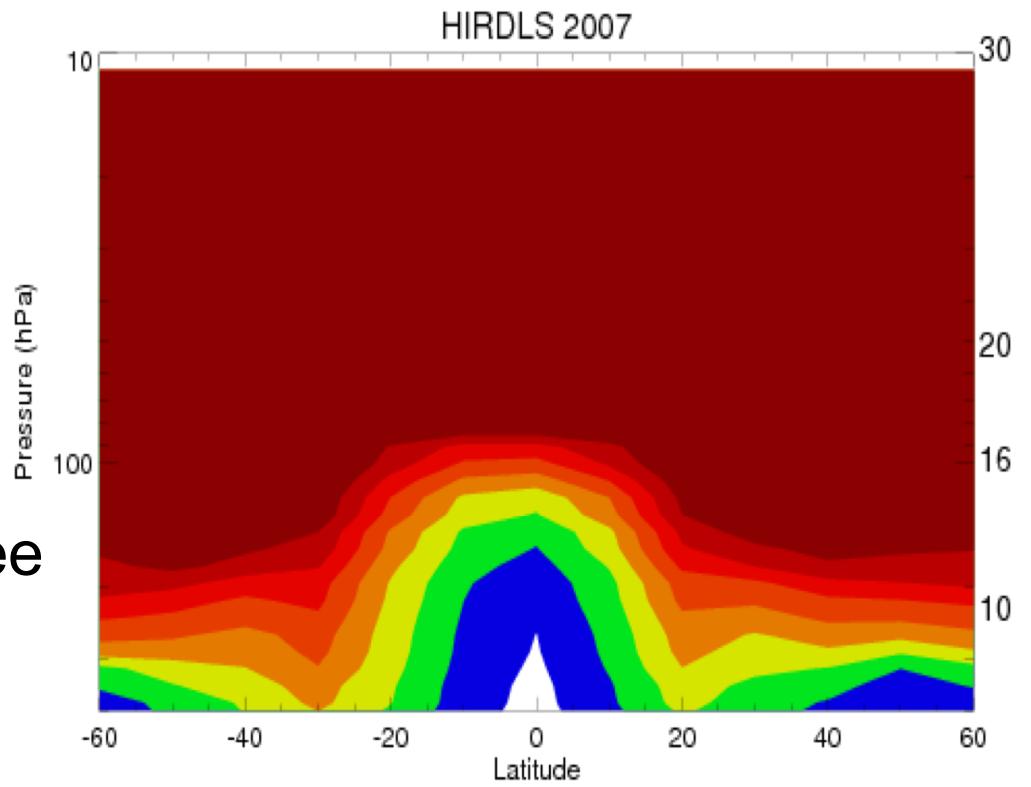
Comparison to
MLS Relative
Humidity allows
study of injection
of water vapor into
the stratosphere



Seeing to Low Altitudes



- Cloud-free frequency indicates ability to see below 10 km >30% of the time in mid- and high-latitudes.
- This indicates ability to see extra-tropical UTLS.



Courtesy Steve Massie

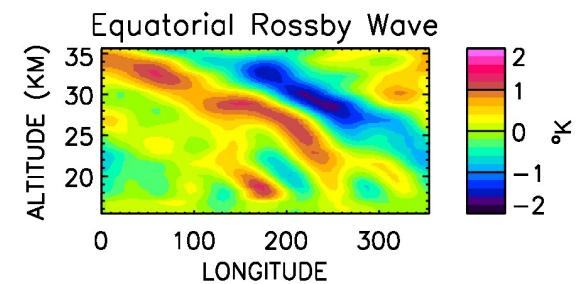
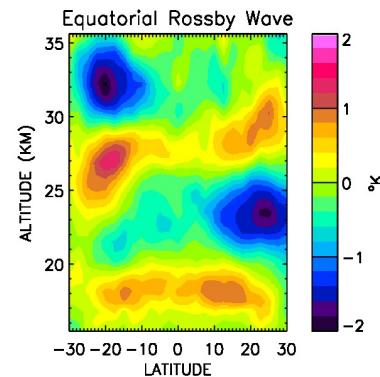
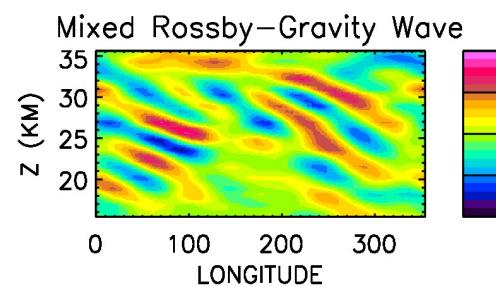
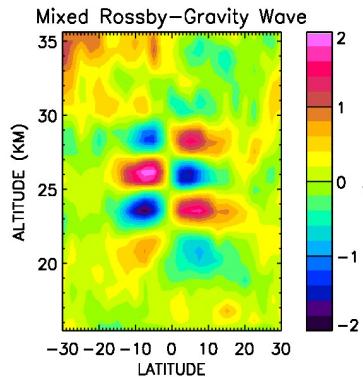
Cloud Free Frequency



10 20 30 40 50 60 70 80 90



High Vertical Resolution Shows Tropical Wave Structure



Left- latitudinal and longitudinal X-sections of Mixed Rossby-Gravity waves (MRG) on Day 305 of 2006. MRG includes WN -1 \rightarrow -5, $\lambda_z = 4\text{-}10 \text{ km}$

Right-Equatorial Rossby waves (ER) on day 354 in 2006. ER includes WN -1 \rightarrow -5, $\lambda_z < 20 \text{ km}$, Period $< 32 \text{ days}$

The wave fronts tilt westward with height, and propagate westward. (Alexander and Ortland, 2010 JGR)

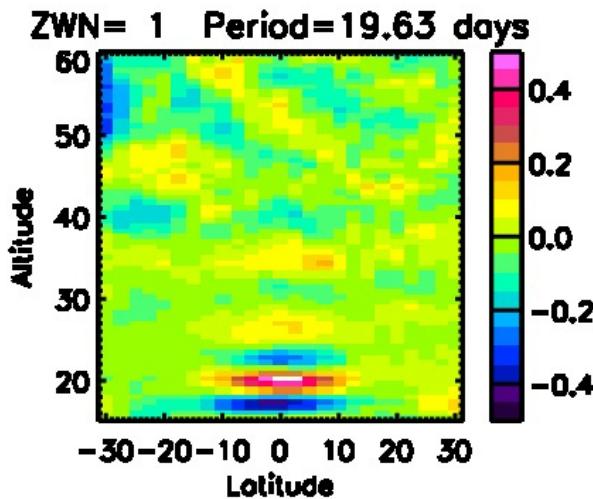


HIRDLS-Observed Kelvin Waves

WN=1-5, periods=3-30day
(Alexander and Ortland, JGR, 2010)



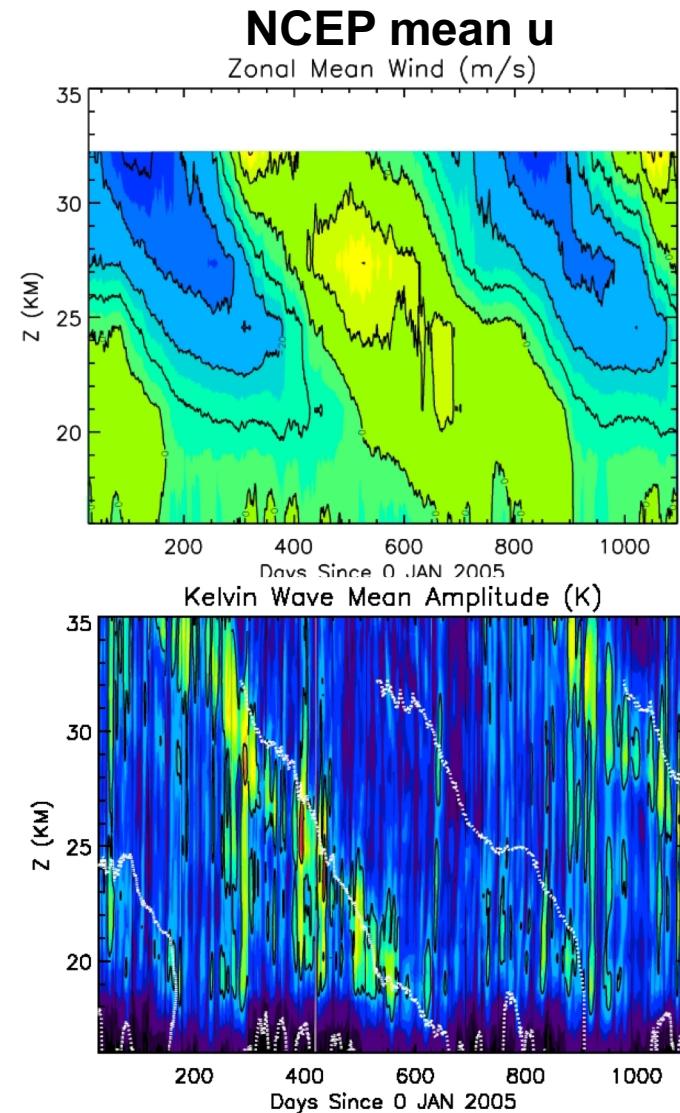
Equatorial Kelvin Waves



Kelvin wave, symmetric about the equator with very short vertical wavelengths.

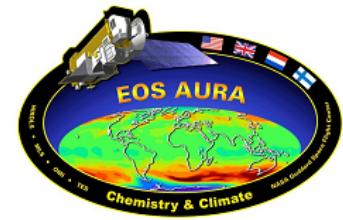
HIRDLS resolution allows seeing 5 Kelvin wave modes, giving a more complete picture of KW drive of the QBO than possible with previous measurements

A clear interannual variation follows the QBO westerly phase descent of the zero wind line

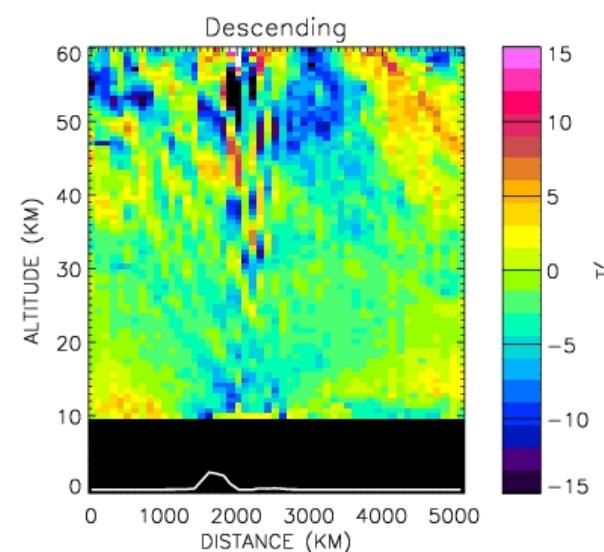
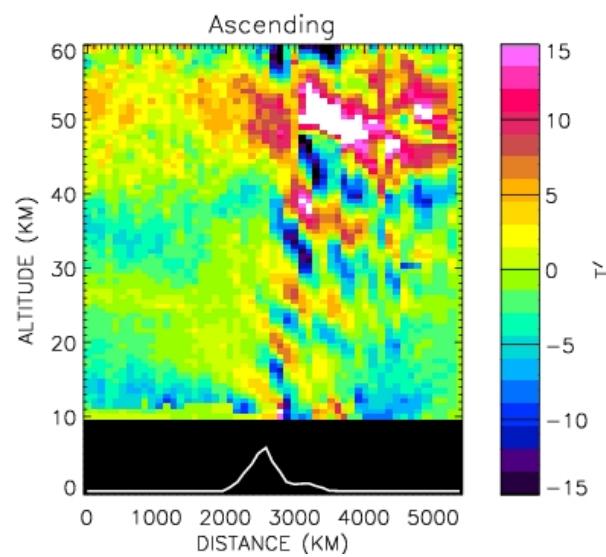
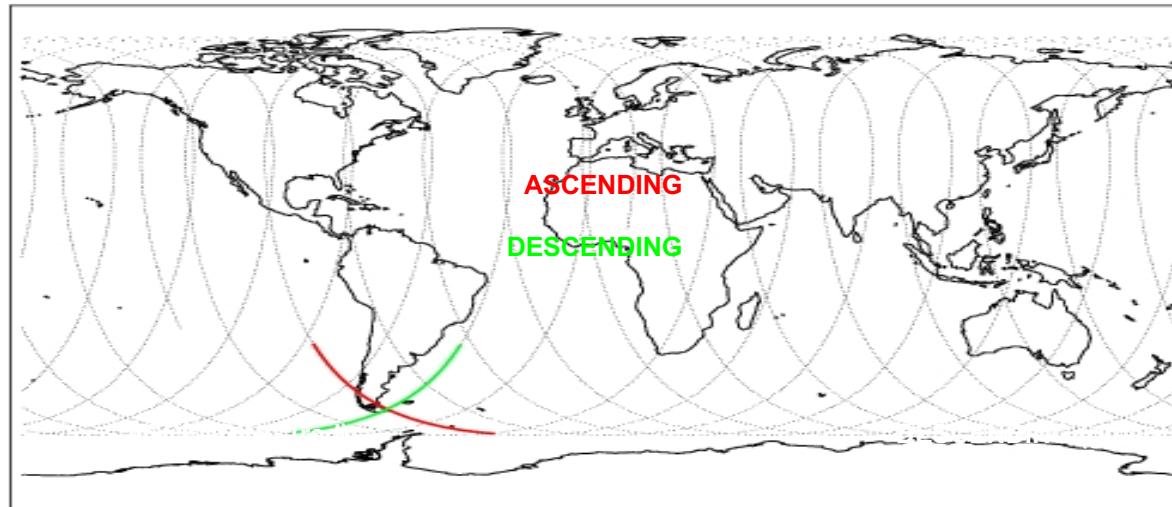




May 2006 Mountain Wave Events (Westerly Winds over Patagonia Generate Gravity Waves)



Alexander
et al. JGR
2008

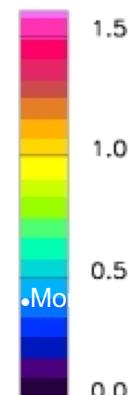
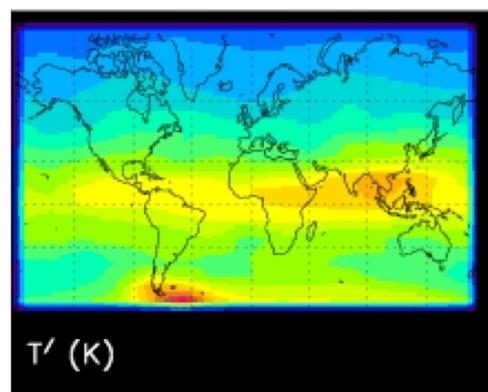




HIRDLS Monthly Mean Map of Gravity Wave Properties: May 2006

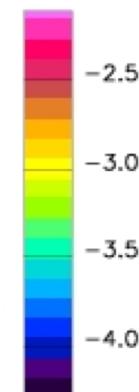
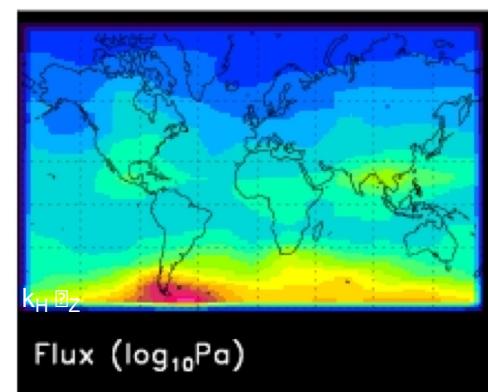


Temperature Amplitude



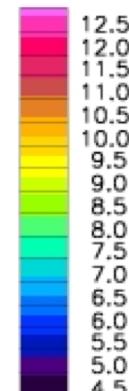
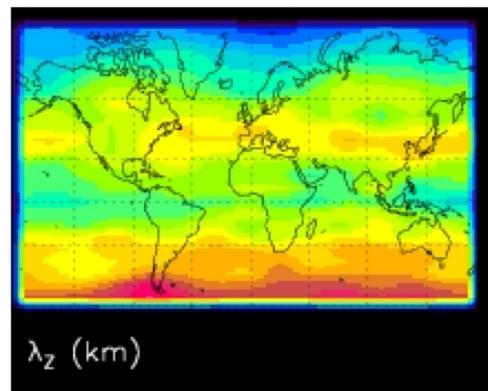
T' (K)

Momentum Flux ($\sim (T')^2 k_H \bar{v}_z$)



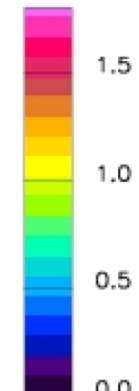
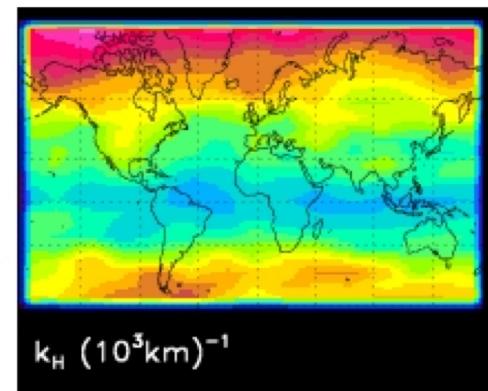
$k_H \bar{v}_z$ (log₁₀Pa)

Vertical Wavelength



λ_z (km)

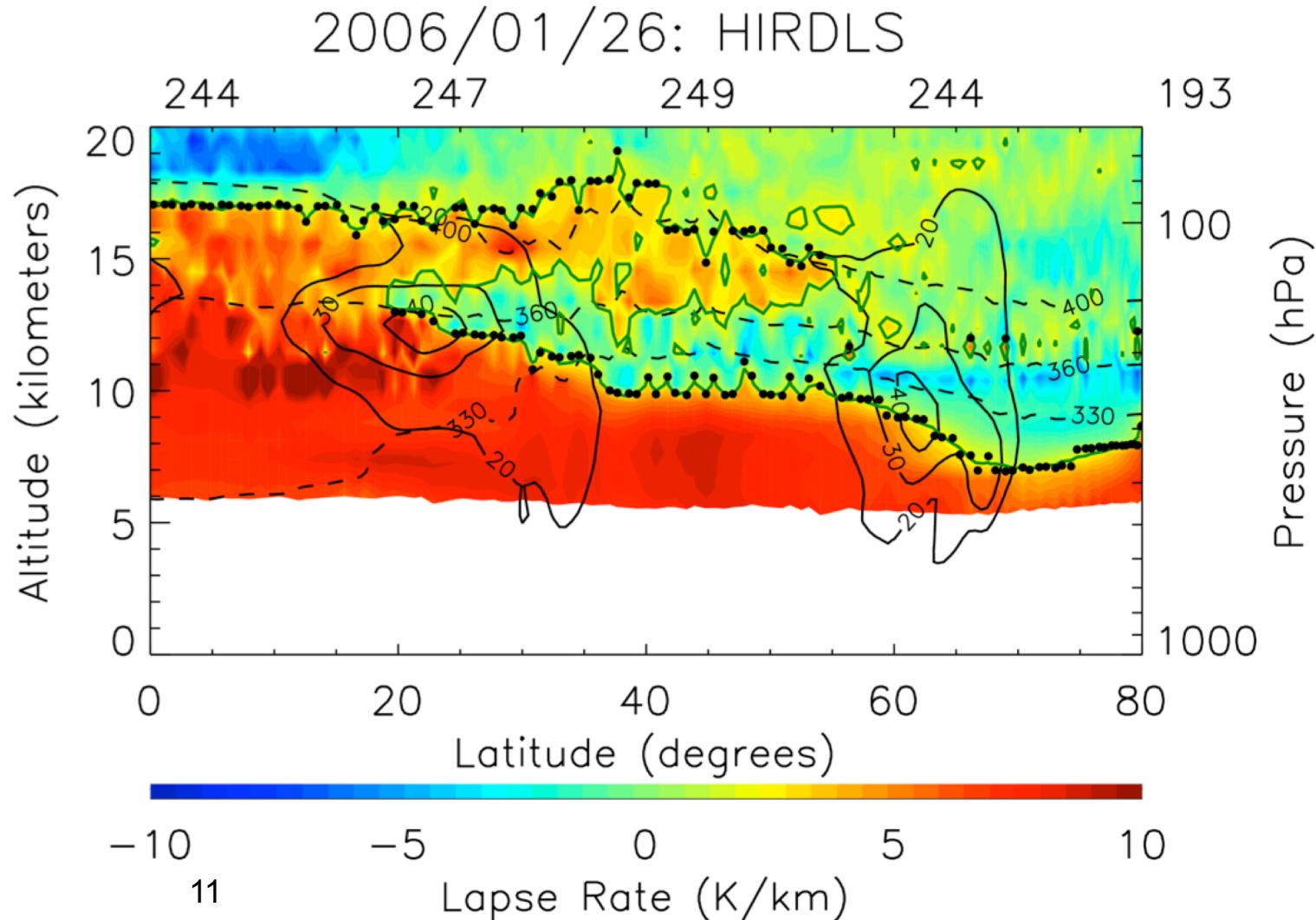
Horizontal Wavenumber



$k_h (10^3 \text{ km})^{-1}$



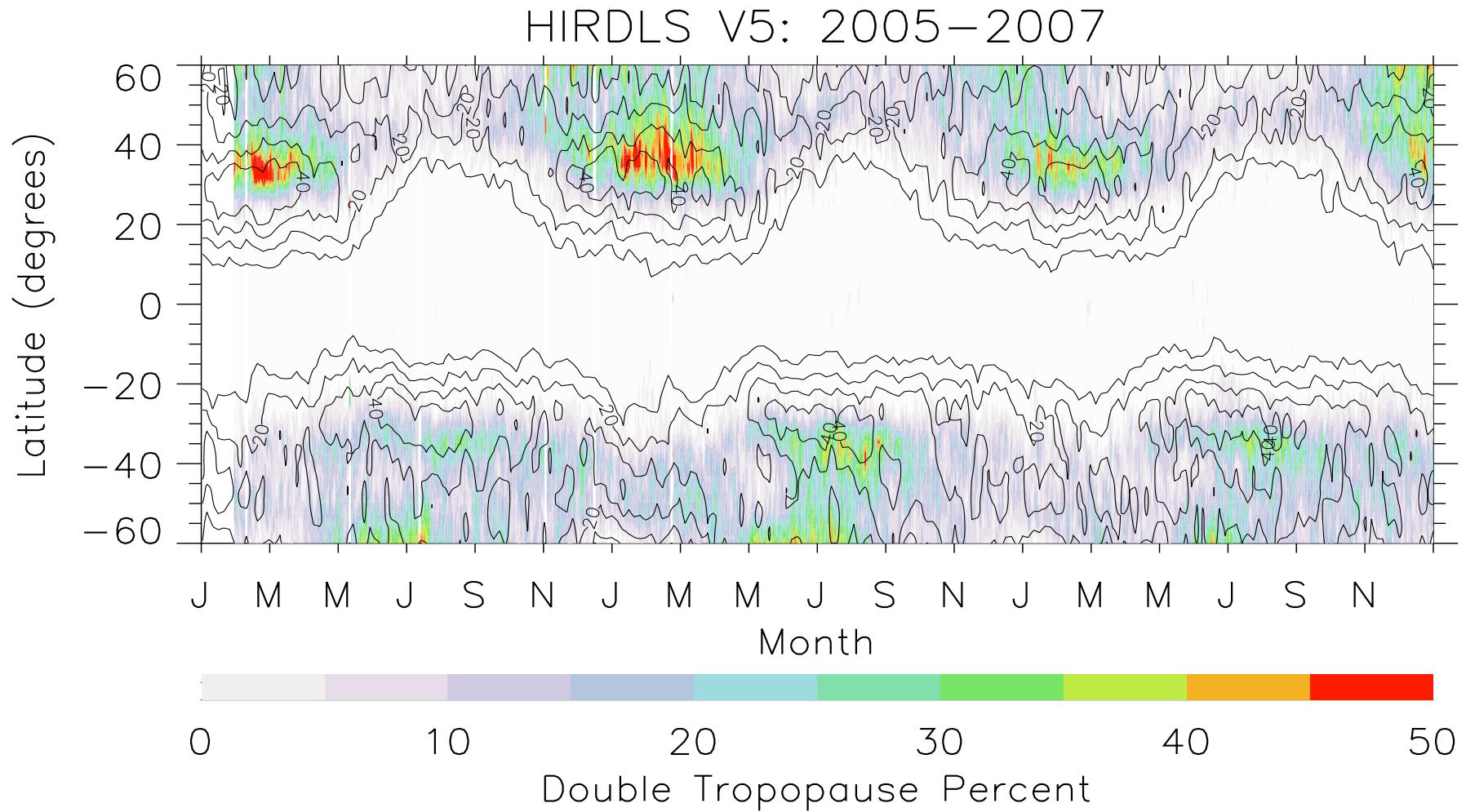
Example of a Double Tropopause



Peevey et al., JGR 2012.



Double Tropopause Frequencies

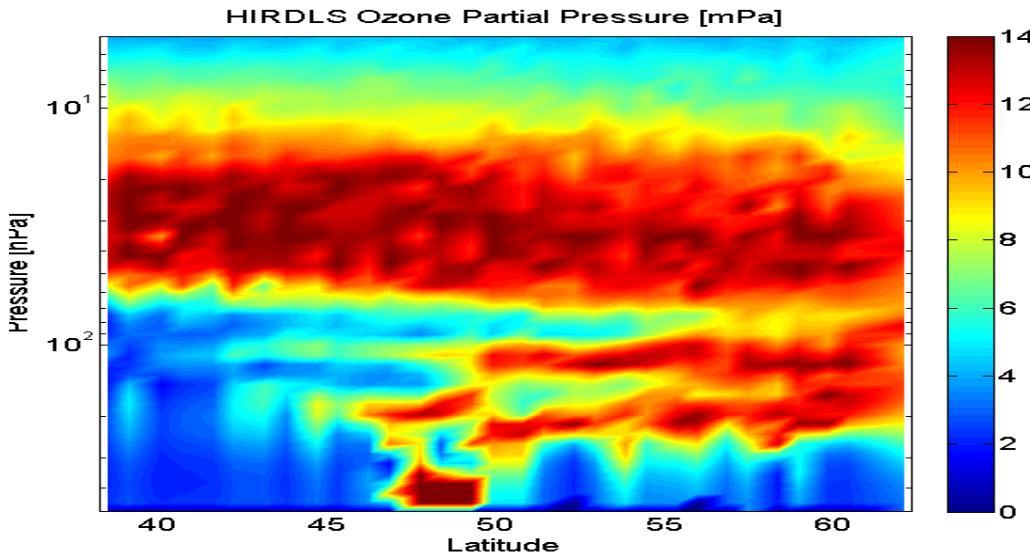


Also Relationship to TIL-JGR 2014

Peevey et al., JGR 2012



HIRDLS Ozone Laminae



Thin O₃ layer tongues frequently seen on maps on θ surfaces, with large latitudinal excursions

They are constrained by Potential Vorticity, and reversible

How are they related to transport and mixing?

Nakamura's (1996) Modified Lagrangian Mean approach uses the area A enclosed by a mixing ratio contour to derive a diffusion equation with effective diffusivity $\kappa_{\text{eff}} = \kappa (L_{\text{eff}}/L_o)^2$

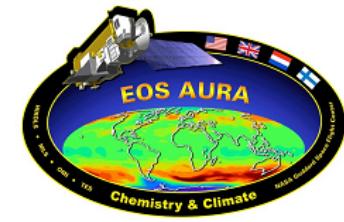
where L_{eff} is the equivalent length, here, as usual, normalized by the minimum length L_o (i.e. the earth's circumference at the latitude)

The value of κ was unknown, so to show the location of barriers to transport, the ratio has conventionally been plotted as

$$\Lambda = \ln (L_{\text{eff}}/L_o)^2$$

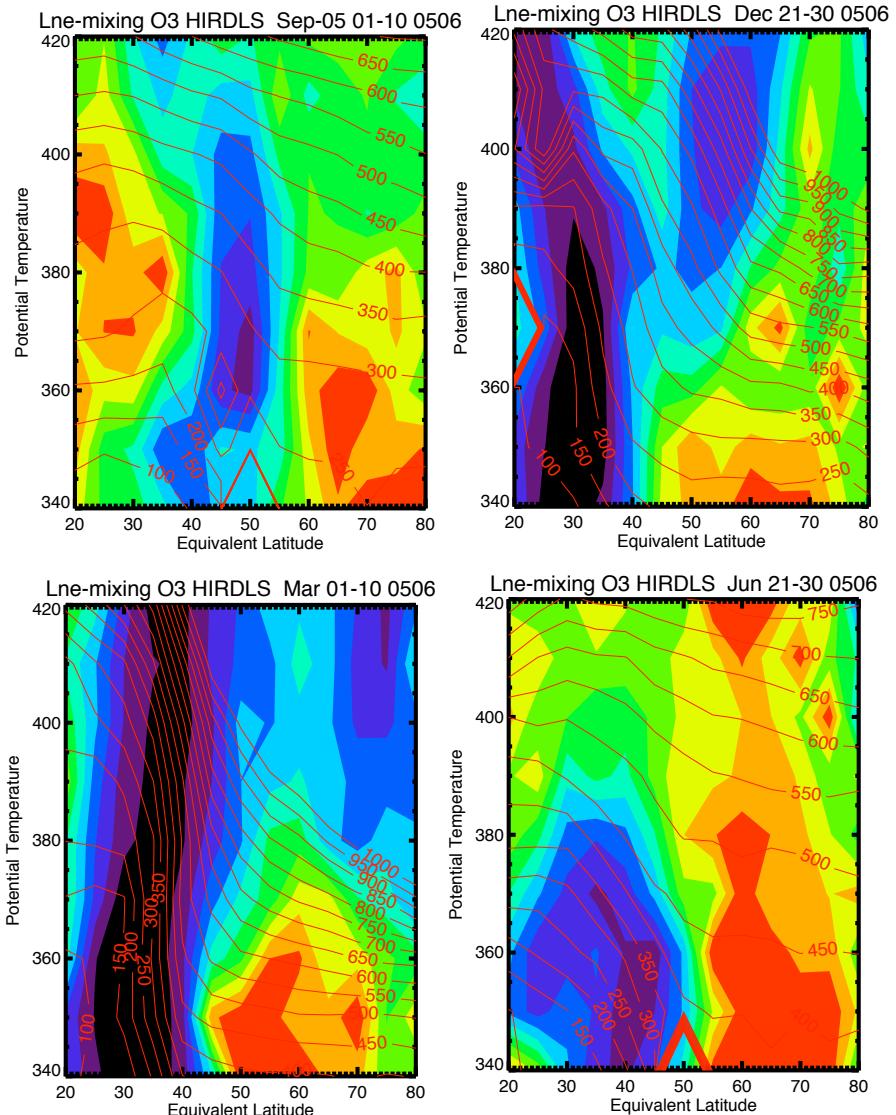


Ozone Cross-Sections with Barriers



Cross-sections of 10 day averages of ozone contours in $\Phi_e - \Theta$ space, with ln of Equivalent Length shown superposed, illustrating barrier regions.

The stronger the barrier, the larger the low-high latitude difference.





An Observational Determination of the Minimum Diffusivity κ



From the measurements and the continuity equation (D' Ovidio et al, 2009)

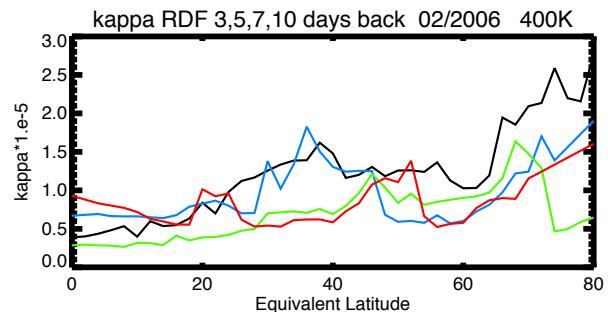
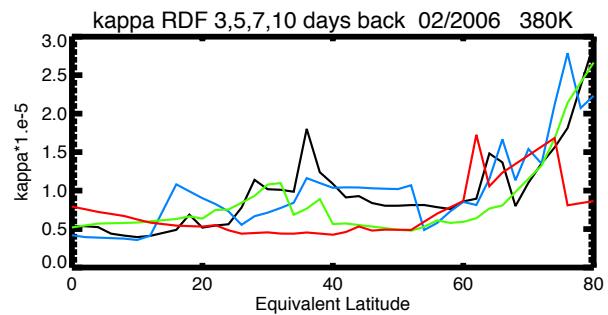
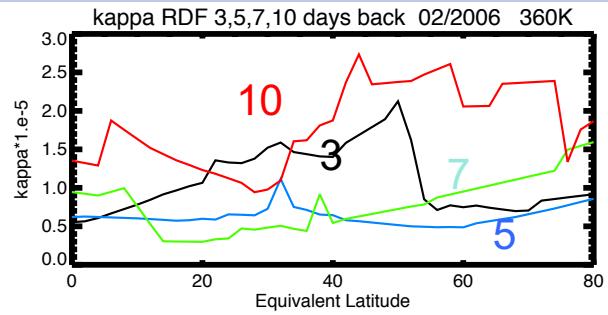
$$\frac{\partial C(\phi_e, t)}{\partial t} = \frac{1}{R^2 \cos \phi_e} \frac{\partial}{\partial \phi_e} \left[\kappa \frac{L^2 \text{eff}(\phi_e, t)}{L_e^2(\phi_e)} \cos \phi_e \frac{\partial C(\phi_e, t)}{\partial \phi_e} \right]$$

We can derive an estimate for the minimum diffusivity, κ , ("little kappa") to be $\sim 0.5 - 1 \cdot 10^5 \text{ m}^2/\text{sec}$ in this region (for Feb 2006).

Determination possible because of time history of an observed trace gas.

- Using RDF to fill the maps adds small-scale features, but the results are relatively independent of the length of the back trajectories

Gille et al., unpublished





Conclusions



- Daily global observations of aerosols and 9 trace gases at 1 km vertical resolution shows and/or confirms a wide range of small-scale processes, especially in the UTLS
- These illuminate small-scale mixing processes, whose capture in models is not always clear
- 3+ years of unique HIRDLS data estimated to meet $\frac{3}{4}$ of original objectives
- These data are capable of leading to model improvement in this critical region of the atmosphere
- Much still can be gotten from these data. Over 100 papers on HIRDLS & data so far.
- Is pathfinder for future smaller IR limb sounders

<http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/HIRDLS/documents/HIRDLS-V7-DQD.pdf>